USING DEPOT INVENTORY POSITION TO DETERMINE TRANSPORTATION MODE OF RETROGRADE REPARABLE ASSETS

THESIS

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Abstract

Air Force logistics policies direct the "expedited evacuation of reparables … to the source of repair", in an effort to allow smaller inventories. Transportation Mode selection is based only on the asset itself. This focus works well when shipping assets out from the depot to a base. When a base ships an asset back to the depot however, the priority of the asset may not be the best way to select the transportation mode. The quantity of the assets at the depot may indicate that fast transportation is unnecessary. The depot may already have enough serviceable assets to meet demand or the number of unserviceable assets already waiting exceeds the depot's repair capacity. If either of these inventory conditions exists, shipping an asset back to the depot using fast transportation is unnecessary and shipping the item via a slower and less costly mode could maintain the same service level. Rather than focus solely on the asset, the inventory of the depot should be involved in mode determination.

This research evaluated current Air Force retrograde transportation mode selection policy. Demand and production data were compared to supply data for Oklahoma City ALC and Ogden ALC to use the inventory position of the depot to select the appropriate speed of transportation. Transportation data was then used to find cost saving potential by finding the difference between mode used and the mode indicated by the depot's inventory position. The analysis found that in 97% of the trials, a mode slower than overnight was suggested and produced a potential cost savings of 38%.

For Mom & Dad

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USING DEPOT INVENTORY POSITION TO DETERMINE TRANSPORTATION MODE OF RETROGRADE REPARABLE ASSETS

I. Introduction

Background

As noted by Masciulli, Boone and Lyle (2002), the Air Force has gone to a supply system that is closely tied to the use of premium transportation. As they put it, “The logic for these policies is a classic trade-off between inventory investment and transportation cost” (Masciulli, Boone, & Lyle, 2002:2). This is echoed in Air Force supply and transportation policies which indicate the need to expedite the shipment of assets back to the depot for repair (USAF, Nov 2003). “The objective of Air Force logistics is to maximize operational capability by using high velocity, time-definite processes to manage mission and logistics uncertainty in-lieu of large inventory levels—resulting in shorter cycle times, reduced inventories and cost, and a smaller mobility footprint” (USAF, Jun 1998:1). “Transportation provides an immediate and effective way to reduce the logistics pipeline. While the cost of some express shipments may be higher than other shipping modes, customer service/mission support is improved while the overall cost of the logistics system is actually reduced” (USAF, Nov 2003:12).

The Air Force ships large numbers reparable assets to and from the depots every year. When a reparable asset is ready for shipment from a base to the depot, the only focus is on the asset itself and its priority (Kahler, 2004). There is currently no concern for what is happening at the depot. Because there is no concern for anything other than moving the asset, the Air Force may be spending more money than necessary using premium transportation when shipping reparable assets back to depot.

Both the supply and transportation systems indicate the need to use premium transportation, but a disconnect between the interpretation of the supply community of "premium" transportation being a desired velocity, and the transportation community interpreting it to be a requirement for overnight air (Masciulli, Boone, & Lyle, 2002), causes the Air Force to overlook the possibility that using slower means would still get the asset to the depot in a reasonable time. An asset that has been deemed not reparable this station (NRTS), and is ready for shipment is assigned a supply priority code based on the item (USAF, Jan 2005). The item is then tuned over to base transportation for shipment which, in-turn, places a transportation priority on the item based on the supply priority (USAF, Nov 2003). At no point is there any consideration for the situation at the depot. Kahler provides an excellent description of this process:

> It is the Reparable Information Management Control System (RIMCS) that puts this process in motion. RIMCS is the Air Force system directly concerned with the "the movement of reparable carcasses from the base … when the local maintenance does not have the capability or authority to repair the item." Based on the RIMCS control code assigned by the materiel manager of a specific item (which are based on the inventory position of the asset), the base supply function puts a supply priority designator of 03 (high) or 13 (low) on the asset (USAF, July 2003: 17). The asset is then transferred to base transportation for movement to the depot…It is at this point that Air Force transportation policy impacts how a NRTS asset moves to the depot. The Transportation priority assignment,

> according to AFI 24-201, *Cargo Movement*, corresponds to the supply priority, although certain other policies (such as GSA small package express and Agile Logistics) may dictate faster movement for certain reparable items that fall within the scope of those policies.
> (Kahler, 2004: 2)

The limited capacity of the depots is not taken into account as it should (Kahler, 2004), and neither is the available inventory. Based on previous research, there seems to be a significant opportunity to save money on retrograde shipments if the inventory position of the depot is made a key factor when determining transportation mode for reparable assets (Kahler, 2004; Kossow, 2003).

Problem Statement

Current Air Force policy requires all retrograde reparable parts be shipped based on priority and requires expedited movement to the depot to support smaller inventories. The actual mode selection is not dictated by transportation regulations, but policies such as Agile Logistics, Two-Level Maintenance, and rapid parts movement dictate the use of fast transportation of reparable assets back to the depot (Kahler, 2004). This generally causes the asset to be shipped to depot using premium air transportation (Kossow, 2003). Using premium transportation causes the Air Force to spend a significant amount of money, and the Air Force may be overlooking an opportunity to reduce costs without reducing the required service level.

As found in previous research, the transportation mode criteria may be inappropriate if the focus of attention is only on the asset itself and not the current situation at the depot (Kahler, 2004). Along with the need to consider the quantity of assets already at the depot waiting to be repaired, mode selection should first consider

whether the depot already has a repaired and serviceable asset available to ship out. If this is the case, the speed at which the broken asset travels back to the depot is unimportant since the depot can send the serviceable one out to the unit. If this is not the case, but the depot already has more than they can repair in a short time, speed of transportation is again not important as the asset will arrive too early and wait.

Research Question

This research will answer the question: Can the serviceable inventory position in relation to demand from bases and the NRTS inventory position in relation to repair capacity of the depot be used to determine the best transportation mode for repairable items? This will be an extension of Kahler's (2004) research, but involve an additional comparison, and looks at the two depots not covered by Kahler. It will include the time periods of Operations ENDURING FREEDOM and IRAQI FREEDOM.

Investigative Questions

The research question will be answered by answering the following investigative questions:

1. What factors determine modal selection in both the Air Force and civilian industry?
2. When is a slower mode of transportation appropriate for Air Force reparable assets and when is it not?
3. How many assets are shipped via premium transportation to depot when the depot stock quantity of serviceable assets is greater than the average daily demand for the item?
4. How many assets are shipped via premium transportation to depot when the depot stock quantity is greater than repair capacity?

5. What would cost savings be if depot stock level indicates a slower mode would be acceptable?

Research Objectives

This research will expand on previous research which has demonstrated the potential for savings if policies are relaxed (Kossow, 2003), and that the repair capacity of a depot should be considered as a factor in determining the mode of transportation for a reparable asset returning to the depot (Kahler, 2004). This research will involve an analysis of whether inventory positions of both the inbound side and outbound side of the Air Logistics Centers can be used as factors in determining when a slower mode would be acceptable and still maintain the required level of service. This will be accomplished by answering the investigative questions.

The first and second questions can be answered by reviewing the literature on movement of retrograde items and Air Force policy about management of and transportation mode selection for retrograde items. This will show what industry and the Air Force considers important for moving retrograde items, and when a slower mode of transportation would be appropriate.

The next step will be gathering and analyzing supply, transportation, and depot repair data for reparable assets. The analysis will involve an extension of the method developed by Kahler (2004). First, the depot's serviceable inventory will be compared to the average daily demand of the item to see how often an item is shipped via premium transportation when one is already available to send back to the base. The idea behind this is that when an item is shipped out NRTS, the base will put in a request for a

replacement. If the depot has one, there is no need to ship the non-serviceable item fast to the depot since it will be able to send out the replacement. For those items that fail the first criteria, the next step will be Kahler's (2004) analysis. The depot stock position of items waiting to be repaired will be compared to the depot's repair rate for the item to find the number that already have more waiting than the depot could repair in the timeframe the asset would move via premium or slower mode transportation. The combination of these two groups will be used to show how many items are shipped by fast transportation when a slower mode would be acceptable to get the item to the depot in a reasonable time to go into the repair process.

Once the numbers of items with higher serviceable stock than demand (comparison one) and the numbers of items with a stock waiting to be repaired grater than capacity (comparison two) have been identified, potential savings will be calculated by finding the difference in the cost of the mode used with the cost of the slower mode. Once these values are found, they can be compared to potential savings found in previous research to show the total savings available to the Air Force by using slower modes when acceptable.

Research Significance

The Air Force, and the entire Department of Defense (DoD) for that matter, spend a huge amount of money sending repairable items back to depot to be repaired. The research this thesis follows shows significant potential for cost savings if mode selection policies are changed. One indicated a potential of $1 million annually by relaxing requirements (Kossow, 2003), and the most recent found an extrapolated potential for

approximately $102 million annually by changing the focus for mode selection (Kahler, 2004). In Based on a portion of the transportation data received for this thesis, the Air Force spent at least $18,165,884 shipping items back to depot from January to May, 2004 alone. It's important to note that this estimate is most likely low considering there were a significant number of blank entries in the cost block of the data. Considering the amount of items the Air Force ships, a better policy for determining transportation mode would be a huge benefit.

Scope and Limitations

Although this study will attempt to gather a more continuous data set for comparison, Kahler (2004:8) notes that the large number of items shipped each day by the Air Force require the data to be limited to a useable set. This study will also only consider CONUS shipments to the Air Logistics Center depots. It will also only consider items that are repaired at Oklahoma City Air Logistics Center (OC-ALC) and at Ogden Air Logistics Center (OO-ALC) in the demand/supply and capacity/supply data calculations.

While this is an extension of previous research, it is again only looking at the efficacy of using depot inventory positions as the determining factor for transportation mode selection and determine potential savings. Further research will be needed to determine how to use this information to change Air Force Policies and how bases could use this method for mode selection. This will be discussed in detail in Chapter V.

II. Literature Review

Introduction

The goal of this thesis is to expand on previous research on the mode selection policies of the Air Force for reparable items being shipped back to the depot. In previous research, both Kossow(2003) and Kahler(2004) found that the current criteria may be inappropriately determined by the priority of the asset. They also found that with the focus on the asset, there is no attention given to what the current situation is at the depot. The argument, as is the case for this thesis, is that “the focus should be on what is happening at the depot” (Kahler, 2004:10). This means the quantity of items already at the depot have an impact on when the depot can get to a newly arrived item and repair it. This research will expand on the finding that quite often, the amount already waiting to be repaired exceeds the capacity of the depot, making the use of premium transportation unnecessary and a waste of money, as the item will arrive quickly only to wait along with the rest of the backlog (Kahler, 2004). The next area to examine is the idea that the depot’s inventory may also have a sufficient quantity of repaired and serviceable items to cover the demand for them, in which case the need to ship a part back quickly is again unnecessary.

There are four areas that will be reviewed to provide a context for this thesis. First is the idea of reverse logistics, as it provides the basis for the retrograde movement of assets back to the depot. Definitions, roles, and practices of current research will be explored. Next is a review of policies and current thought on how the Air Force manages repairable items. The third area is transportation mode selection

which will cover current business research and how the Air Force selects mode of transportation. Finally, previous graduate research will be reviewed to find what possibilities previous researchers have found to improve the way mode is selected for retrograde reparable assets.

Reverse Logistics

The concept of reverse logistics gives an overall background for the basis of this thesis, namely the retrograde or reverse flow of reparable assets to the depot to be repaired. This section will discuss reverse logistics in terms of the various definitions, roles and importance of the concept, and what constitutes an effective reverse logistics system. This will give a basis of the current ideas to work from. Although the idea reverse logistics is a "…broad concept, encompassing many activities within and outside of, logistics…" (Stock, 1999:6), the focus will remain on the concepts of the movement of items back up the supply chain.

Although the actual practice of reverse logistics has been going on for some time, the term is fairly new and its source is difficult to trace (De Brito & Dekker, 2002). Robert Banks notes in an article in Army Logistician that "[r]everse logistics has existed in one form or another since the advent of the Army…" (Banks, 2002: 3). Many authors describe reverse logistics as a fairly new concept and has only recently started gaining importance and interest (Dowlatshahi, 2000; Rogers & Tibben-Lembke, 2001; Mason, 2002; Carter & Elleram, 1998, Blumberg, 1999). Rogers and Tibben-Lemke (2001:129) note that "while there is new interest in reverse logistics, little is known about the size and scope of reverse logistics activities".

Definition

There seem to be as many definitions of reverse logistics as there are authors. The earliest version found is provided by DeBrito and Dekker from the Council of Logistics Management in the early 1990's:

> …the term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all relating activities carried out in source reduction, recycling substitution, reuse of materials and disposal (De Brito & Dekker, 2002:2)

As noted by Rogers and Tibben-lembke(2001), this highlights the fact that much of the early emphasis was on a goal to reduce the environmental impact of a supply chain. The most commonly referenced definition for modern reverse logistics is given by Rogers and Tibben-limbke which is based on the Council of Logistics' definition of logistics:

> The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or proper disposal (Rogers & Tibben-Limbke, 2001: 130)

Banks (2002:3) gives a definition as being, "…the timely and accurate movement of serviceable and unserviceable materiel from a user back through the supply pipeline to the appropriate activity". This seems to be the most applicable for use in this study. Several authors (DeBrito & Dekker, 2002, Jayaraman et al. 1997) also pointed out that many reverse logistics models involve a closed loop system, where items flow both in the forward and reverse directions. This is also applicable for this study. Many authors (for example, DeBrito & Dekker, 2002; Dowlatshahi, 2000; Rogers & Tibben-Lembke, 2001; Carter & Elleram, 1998) indicate that reverse logistics most likely started out with improving the environment in mind. Rogers and Tibben-Lembke (2001) also point out

that due to this, the terms green logistics and environmental logistics have been used interchangeably with reverse logistics and although there is some overlap, there are differences between them. Figure 1 shows where the overlaps and differences between reverse logistics and green logistics are. Not shown in figure 1 is another aspect that relates to both green and reverse logistics. This is product recalls, the special case where a firm self initiates reverse flow on most or all of a product immediately due to safety or health problems with the product (DeBrito & Dekker, 2002).

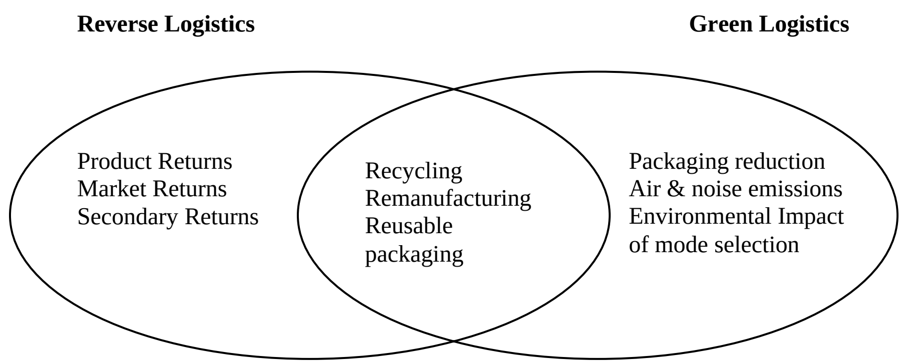

Figure 1. **Overlap of Reverse and Green Logistics**
(Rogers & Tibben-Lembke, 2001: 131)

The two basic areas of reverse logistics according to Rogers and Tibben-lembke (2001) are those concerning the return of product and return of packaging. For the purposes of this research the focus is on the product side, as reparable items should be considered a product. Most authors note that the reasons products are returned are for remanufacturing, refurbishing, recycling or disposal (Rogers & Tibben-Lembke, 2001; Blumberg, 1999; Carter & Ellram, 1998; Andel, 1997; DeBrito & Dekker, 2002).

Roles and Importance

Nearly every article agrees that the importance of reverse logistics has been steadily increasing. Originally, the role of reverse logistics was centered mainly on environmental compliance (Mason, 2002). But many of the articles indicate that reverse logistics is a way to gain an advantage over competitors and has a large potential for cost savings and added revenue.

According to James Stock (2001: 5), reverse logistics is "the newest differentiator" between firms, noting that many of the traditional ways firms competed such as quality, speed of delivery, on-time, etc., are the "price of admission" and most firms are fairly equal in these or they are not even considered. Mason (2002: 43) agrees with this idea, noting that firms are "…moving from a focus on customer service to an emphasis on complete customer satisfaction".

Another reason cited for the increase in importance is the need to reduce the costs and improve efficiency. According to the 2004 book *Supply Chain Management* developed by the Supply Chain Management Institute, it is estimated that retail customer returns accounted for approximately six percent of revenues and amounted to almost $44 billion, with return management accounting for four percent of a firm's logistics costs (Rogers, et al., 2004). The book points out that "the magnitude of these numbers demonstrates the need for management attention to the return process" (Rogers, et al, 2004: 147), and cites returns management as one of the eight major processes of supply chain management. Tom Andel (1997: 61) notes, in an article in *Transportation and distribution*, "By ignoring the efficient return and refurbishment or disposal of product, many companies miss out on a significant return on investment". Banks (2002:3) points

out that industry, and now the Army, has placed more importance on reverse logistics due to the fact that it "makes the greatest and most efficient use of existing resources". He argues that by using existing resources optimally, the firm maximizes their buying power.

Effective Reverse Logistics Systems

There are many aspects pointed out by the authors as to what makes a reverse logistics system effective. Although not directly applicable to this research, many authors point out the need for firms to ensure the timely processing of items once they are received back. Both Stock (2001) and Rogers and Tibben-Limbke (2001) point this out as a major reason firms have a less than optimal system. Mason (2002) and Andel (1997) identify that many firms do not put enough importance on their returns. Granted, the reverse portion will never be as high a priority as the forward side, the resources involved necessitate a reasonable amount of attention (Andel, 1997; Mason, 2002, Rogers, et al., 2004). Stock (2001: 10) identifies this as his "seventh deadly sin" of reverse logistics. Banks (2002) agrees with this idea in a military setting, noting that only until recently has the Army begun to give a reasonable attention to its retrograde movement process.

As pointed out by Khaler's (2004) research, the two most important aspects concerning this thesis are the efficiency and synchronization of the system. As noted earlier, reverse logistics is becoming a point of differentiation between competitors (Stock, 2001). The idea of synchronization is found in the idea that all levels of the supply chain need to know what is coming and from where, along with knowing what is already there. Rogers and Tibben-Lembke (2001) point out that they found very few good reverse logistics management systems, and few firms have a successful automated

returns system. As noted by both Kahler (2004) and Kossow (2003), there is a need for the ability to take into consideration what is upstream in the pipeline to make better use of transportation and supply resources.

Reparable Item Management

This section will discuss Air Force policy and practices concerning the management of reparable assets. First, it will review what a reparable item is and what is involved in the management of these types of items. Then it will go into depth on how the how the Air Force manages its reparable pipeline. As with previous studies this review will not directly involve the theories behind reparable item management. The main focus will be on how the Air Force manages its reparable pipeline.

Reparable Inventory Management

The basic definition and inventory theory for reparable items is concerned with items “which are repaired (returned to usable condition)” rather than disposed of when they break or become unusable (Guide & Srivastava, 1997:1). The Air Force defines them as items which are “not consumed in use” (USAF, 1994: 3). The basic tenet around an item being reparable is that it is generally a very high cost item that can be repaired and sent back out more economically than simply buying a new one (Guide & Srivastava, 1997). Banks (2001: 5) notes that military weapons systems are “…more sophisticated, logistically complex, costly, and automated that at any time in our history”. He goes on to point out that these items will eventually fail and need to be replaced, but repairing them is going to be more cost effective. Although Banks (2001) is talking about Army

equipment, it is reasonable to say Air Force systems are very similar in being expensive and complex.

Management of reparable items is primarily concerned with how to optimally stock parts at forward bases and a central repair depot which repairs failed parts that it receives from the bases with the objective of maximizing, in the case of the Air Force, aircraft availability while staying within a budget constraint (Guide & Srivastava, 1997). Guide and Srivastava (1997) also point out that this should not be confused with spares inventory, which although it serves the same basic purpose, doesn't necessarily have all reparable parts and is not concerned with the return flow of parts back to the depot.

Jayaraman et al. (1997) point out that an environment where items flow in both directions from customer to manufacturer create a closed loop system, since most of the products and materials are conserved and reused. They also point out that since the return flow of items is supply-driven there is a large amount of uncertainty about the quantity, time and condition of the items coming back. The Air Force reparable system follows such a model, with unserviceable parts moving from the bases back to depot for repair and serviceable parts flowing to the bases. Kossow provides an excellent review of how this pipeline works and gives a conceptual model seen in figure 2. Kossow (2003) points out that there are two portions of the system. First is the forward portion which starts when a user requests a part and ends when they receive it, and the retrograde, which starts when a part is deemed unserviceable and ends when the item has been repaired.

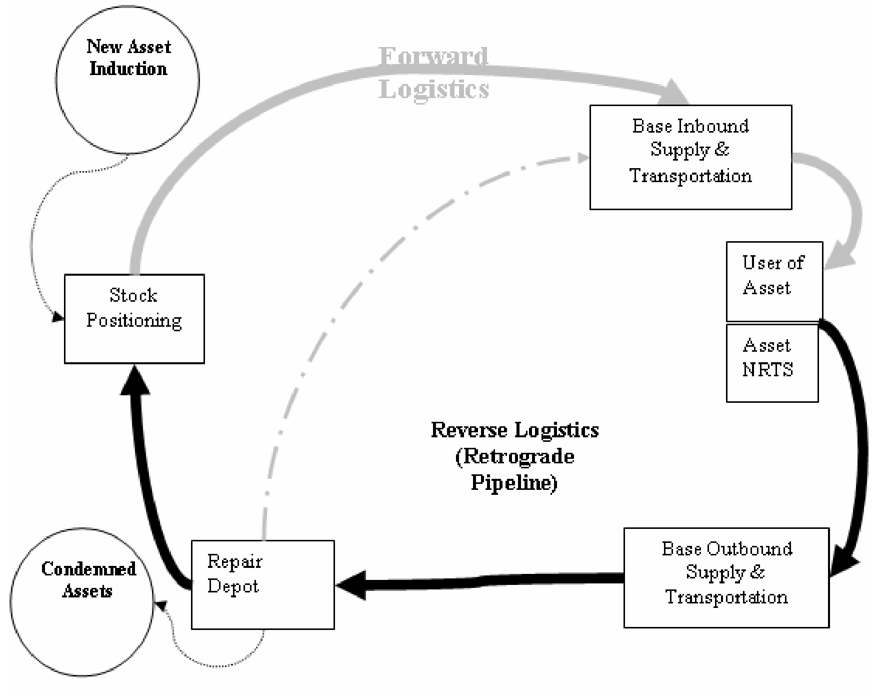

Figure 2. Conceptual Model of Reparable Asset Logistics System (Kossow, 2003:10)

Air Force Reparables

As noted by Kahler (2004) there are two primary regulations that govern the management of the Air Force Reparable pipeline. These are the policy directive AFPD 20-3, *Air Force Weapon System reparable Asset Management* (USAF, Jun 1998), and the Air Force Instruction which implements this policy, AFI 21-129, *Two Level Maintenance and Regional Repair of Air Force Weapon Systems* (USAF, May 1998). The basis for the policy is set out in the first paragraph of AFPD 20-3:

> Air Force logistics must focus on improving operational units' capability by integrating and applying state-of-the-art business practices across all logistics functions and processes. The objective of Air Force logistics is to maximize operational capability by using high velocity, time definite processes to manage mission and logistics uncertainty in-lieu of large inventory levels—resulting in shorter cycle times, reduced inventories and cost, and a smaller mobility footprint. These business practices are also

> critical to achieve Air Force Agile Combat Support goals. (USAF, Jun 1998: 1).

AFI 21-129 sets the guidelines for the pipeline and there are two things which are of interest for this research. First is the requirement for "expedited evacuation of reparable items by the base to the appropriate depot" (USAF, May 1998:8) and calls for "..fast, time-definite, best value transportation…", (USAF, May 1998:11), with delivery performance, speed, flexibility, and consistency being the top criteria. Previous research has also shown that as a general rule, the request for a reparable asset typically occurs when a weapon system maintenance activity has declared a reparable asset unserviceable and no replacement part exists in local inventory stocks (Briggs, 1996:37). Figure 3 shows the Air Force's concept of the pipeline, and gives a sample of pipeline flow measures. It's interesting to note that transportation cost is one of the measures mentioned on the flow chart. This indicates the Air Forces pipeline is transportation based, using transportation capability to meet demand rather than large inventories (Kahler, 2004). Another item of interest is the requirement that 2LM [2-level maintenance] coded items will be repaired on-demand, namely when one is required (USAF, May 1998). This may become important since this thesis looks to test the ability to use the depot's finished inventory as a transportation mode criterion along with the repair capacity. If they are only repairing on demand, there may be little if any finished inventory sitting at the depot waiting for a demand and this test may fail to be useful.

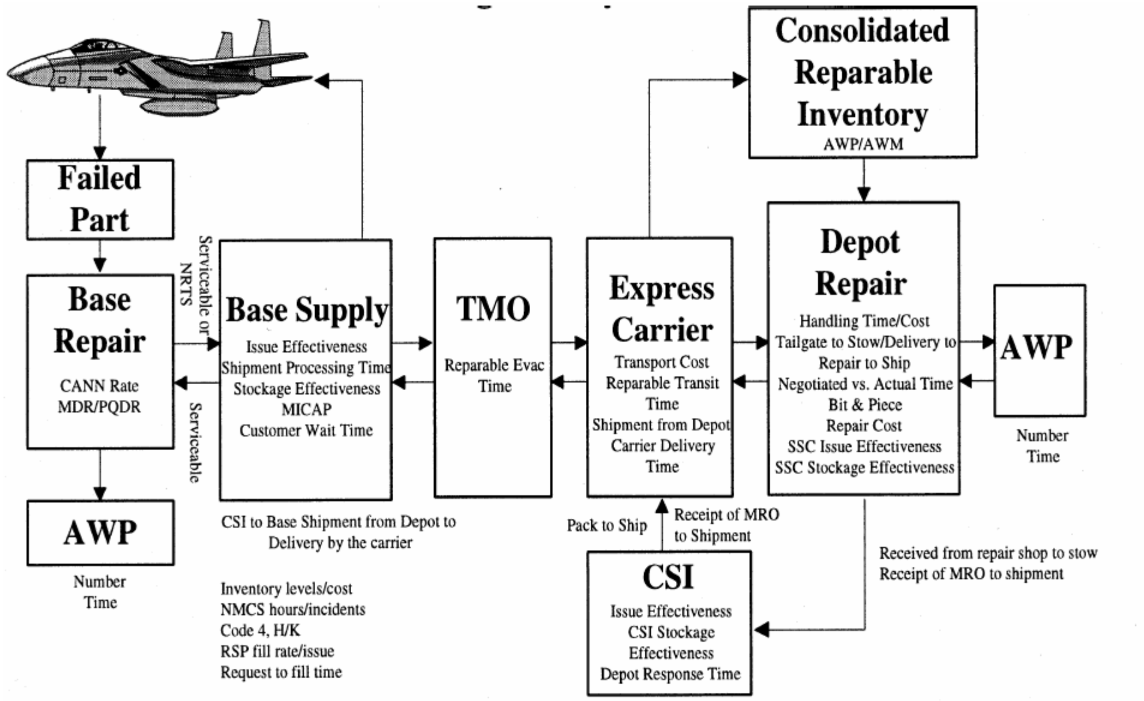

Figure 3. Sample Metrics of Pipeline Flow Measures (USAF, Jun 1998:6)

Transportation Mode Selection

This section will cover transportation mode selection. Since the previous section showed the Air Force to be heavily reliant on transportation in its reparable inventory management, it's important to know what goes into mode selection and why. First, what goes into mode selection and why will be discussed. Then Air Force policy on mode selection will be reviewed.

Mode Selection

The best description of why firms need to consider transportation mode selection is given by Stock and Lambert (2001:354); "[t]ransportation is one of the most significant areas of logistics management because of its impact on customer service levels and the firm's cost structure". They go on to note that transportation costs can account for 10 to

20 percent of a products price, and effective management can have a great impact on a firm's profitability. Henry Giese (1995), in a 1995 article in *Transporation & Distribution* agrees with this idea. He points out that effective traffic management can be a very competitive tool and in turn a source of differentiation "since transportation plays such a big role in our economy" (Giese, 1995:75). In general, transportation costs are the largest in the logistics element (Coyle, Bardi, & Novak, 2000).

A commonly noted concept the authors point out is the need for firms to consider total logistics costs when selecting a mode of transportation (Stock and Lambert, 2001; Coyle, Bardi, & Novak, 2000; Sheffi, Eskandari, & Koutsopoulos, 1988). Stock and Lambert (2001), give an excellent definition for this noting that a firm needs to consider ways to reduce all of its logistics function costs as an integrated system while meeting its customer service goals rather than just looking at them independently. They identify six logistics cost categories:

1. Customer Service Level
2. Inventory Carrying Costs
3. Transportation Costs
4. Lot Quantity Costs
5. Warehousing Costs
6. Order Processing and Information Costs

(Stock & Lambert, 2001: 29)

The important thing to note here is that when costs of one are decreased, it will cause one or more of the others to increase (Stock and Lambert, 2001; Coyle, Bardi, & Novak, 2000). It's this interplay between the six cost functions and the need to meet customer service levels that make transportation mode selection so important.

Throughout the literature, customer service level and cost are the main two determinants of modal choice, with service generally cited as most important and cost

next. Giese (1995:75) points out “it is the responsibility of traffic personnel to try, continually, to reduce transportation expense, at the same time keeping in mind that good service must be maintained”. Kahler (2004) makes a good point of the fact that the term “customer service” here is concerned only with measures of how well the carrier moved the shipment.

Several articles examined the major determinants both before deregulation, where transportation rates were fairly inflexible, and after, using 1980 as the breakpoint between the two periods (McGinnis, 1990: Murphy & Hall, 1995). McGinnis (1990: 17) identified the following six variables that most influenced mode selection in the studies he reviewed:

1. Freight Rates
2. Reliability
3. Transit Time
4. Loss, Damage, Claims Processing, and Tracing
5. Shipper Market Considerations
6. Carrier Considerations

The first is the cost variable, with the other five considered service variables. These appear to be a generally accepted group as Murphy and Hall (1995) used them as the framework for their study.

In the period before deregulation, as would be expected since rates were inflexible, both McGinnis (1990) and Murphy and Hall (1995) found that service level was the most highly valued determinant, but rates were still considered fairly important. In the period after deregulation, freight rates became more important, but in both studies, the variable reliability remained the most important factor (McGinnis, 1990: Murphy & Hall, 1995).

Another interesting finding in both the McGinnis (1990) and the Murphy and Hall (1995) studies is that when considered separately, the service variables are not always more important than rates, although this is more true in the period after deregulation. McGinnis (1990:17) notes in his conclusions "The priorities among service variables vary. This means that any generalizations that service is usually more important should be qualified. This is because some service variables may be more important that freight rates, while others may be less important in a particular situation". Murphy and Hall's (1995:37) conclusions agree with this as they found evidence to support their proposition that "the relative importance of freight rates and service variables will vary across situations". This seems to support the idea that when considering what transportation mode to use, the choice needs to be made with consideration for the total cost function of logistics and needs to be flexible enough that "service" does not always override cost.

Air Force Transportation Mode Selection

The review of the Air Force's reparable inventory management policy showed that the Air Force goal is to maintain a smaller inventory and use high velocity processes to manage uncertainty. As several authors point out, this causes in the Air Force supply policy to be tied heavily to transportation, using the tradeoff between inventory and transportation costs, (Kahler, 2004; Masciulli & Cunningham, 2002; Masciulli et al., 2002). This dependence on transportation makes mode selection all the more critical.

Three Air Force and DoD regulations are applicable in determining transportation mode (Masciulli & Cunningham, 2002; Kahler,2004). Kahler (2004:25) provides a description of these:

> the *Defense Transportation Regulation* (DTR), Part 2 (DoD, 2000) which sets time standards and allows for expedited movement of cargo when needed; AFI 24-201, *Cargo Movement* (USAF, Nov 2003), which is the overarching Air Force transportation regulation and *Air Mobility Command Freight Traffic Rules*, Publication Number 5 (AMC, 1999), which applies DoD transportation rules to all carriers hauling freight for the DoD. These three regulations cover the span of the movement of freight within the DoD and the Air Force.

The previously reviewed regulations AFPD 20-3 (USAF, Jun 1998) and AFI 21-129 (USAF, May 1998), also provide direction. As mentioned before, they require the need to expedite the evacuation of reparable items for shipment and the use of fast, time-definite, best value transportation, although all the authors agree that with the exception of certain situations outlined in AFI 24-201, none of the regulations actually dictate a mode of shipment (Kalher, 2004; Kossow, 2003; Masciulli, et. al, 2002; and Masciulli & Cunningham, 2001).

The main regulation that provides guidance for shipment mode of reparable items is AFI 24-201 (Masciulli & Cunningham, 2002; Kahler, 2004). First, Chapter two establishes time standards for both the processing and shipment of a reparable at 24 hours, and the shipment delivery time standards which for shipments of interest in this study, CONUS retrograde, at one day (USAF, Nov 2003). It also states that "Commercial air express small-package delivery service… is the norm for Agile Logistics/2LM/Rapid Parts Movement shipments to met Air Force sustainment goals."(USAF, Nov 2003: 12; Masciulli & Cunningham, 2001:4 ; Kahler, 2004:25-26 and Kossow, 2003: 16-17) Chapter six goes on to mandate the entire DoD to use the GSA Multiple Award Schedule, DOD Domestic Express Small Package Blanket Purchase

Agreement Carrier program, which means all reparables will be shipped by express air with the few exceptions noted in paragraph 6.2. (USAF, Nov 2003: 29)

Studies on Air Force Mode Selection

This study follows four others that have explored the Air Force's transportation mode selection. Two of these looked at the forward or depot to base portion of the pipeline (Masciulli & Cunningham, 2001, Masciulli, et. al, 2002), and two that concentrate on the retrograde portion (Kossow, 2003 and Kahler 2004).

The article by Masciulli and Cunningham (2001) was based on research that looked to see if the shipping policy of mission capable (MICAP) parts going from the depots back out to the using bases was optimal based on cost. The research first used a simulated data table to compare the rate difference between express air and express less-than-truckload modes based on weight and distance. They found that each mode was the less expensive mode about half of the time. Figure 4 shows the breakout of the rate differences and shows how they found that as weight increases and distance decreases ground is the best option, and vise-versa for air (Masciulli & Cunningham, 2001). Next they looked at actual MICAP shipment data to see if there was any potential for cost savings by considering ground instead of air. They found that, for the most part, the shipments were going by the lowest cost mode, namely air. They did find that out of 3,451 shipments there were 633 instances were the shipment should have gone by ground. By using a combination of modes, they found a potential 11 percent cost savings.

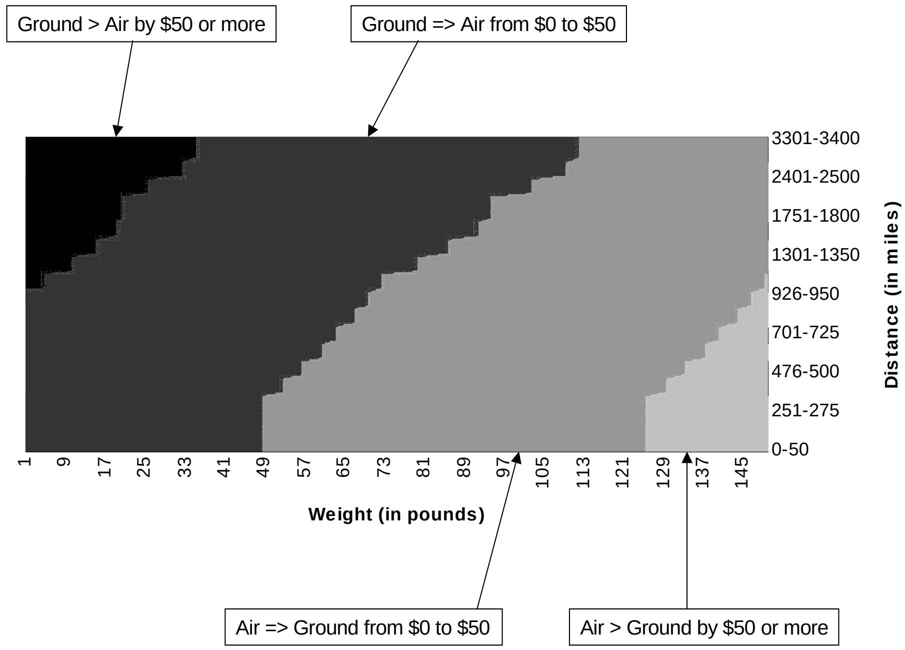

Figure 4. Differences Based on Weight and Distance (Masciulli & Cunningham, 2001:4)

Additionally, they questioned whether the use of express air is "so ingrained in the Air Force and DoD corporate culture it is automatically assumed and used as the carrier for MICAP items and other time-critical shipments without regard to cost, distance and other factors?" (Masciulli & Cunningham, 2001:5; Kahler 2004:27). During the course of the research they found instances where items were shipped via overnight air that traveled distances from 72 to as little as 11 miles. They also found cases where items were shipped by air when organic vehicle operations were already doing delivery runs between the two bases.

The next study was conducted by the Air Force Logistics Management Agency (AFLMA) in response to a question from the Strategic Distribution Management

Initiative Board of Directors as to whether the Air Force uses premium transportation too frequently (Masciulli, et. al, 2002). They examined both the policies driving the use of premium transportation and looked at shipping data to validate the use of premium transportation. The results of the shipping data analysis showed that using premium transportation was for the most part a "wise and economical decision" (Masciulli, et. al, 2002:7). They did find also that opportunities may exist to use other modes in the CONUS and recommended further study. As mentioned in Kahler's (2004) review, they described the disconnect between the Air Force supply and transportation communities' definition of premium transportation which as Kahler (2004:28) put it, "…seem to confirm the previous study's notion of the use of premium over-night air is ingrained in the Air Force Corporate Culture".

The first study to look at the retrograde portion of the pipeline was conducted by Kossow (2003). The goal of this study was to "review the retrograde logistics pipeline and the processes and policies that drive modal choice for shipments of reparable assets…"(Kossow, 2003:7). This study analyzed retrograde shipment data to compare the differences in efficiencies of using air and less-than-truckload (LTL) modes in different combinations while assuming an equal service level. The results showed that the use of a lowest cost mode with consolidation of LTL shipments method gave a potential for $62,312 in savings based on the data that was analyzed over using only a simple lowest cost method. This is consistent with the first two studies that found a combination of modes was the best option. This study also recommended a shift in policy that would relax the service requirements allowing more use of the LTL option and research into ways to determine what service level was needed.

Kahler's (2004) research was the first to explore this area of Air Force mode selection criteria. The goal of this study was to evaluate the possibility of using depot repair capacity as a factor in selecting transportation mode for reparable assets being shipped to the depot from CONUS locations and determine the potential savings of this method. The study compared the depot stock position of inbound reparable assets to a depot repair capacity for the item. If the amount already awaiting repair is greater than the capacity, then premium transportation shouldn't be used unless it is the lowest cost option. The results showed that for items with 11 or more shipments, the stock of waiting assets exceeded the calculated monthly capacity in 86.7 percent of the trials. He then drew a random sample out of this pool and found a potential cost savings of $1,497.91 by using ground transportation for the shipments that occurred on the 14 days that the supply data was drawn. By extrapolating these savings back out as shown in table 1, he found a potential savings of over $5 million for the period the study covered.

Table 1. Extrapolation of Savings (Kahler, 2004: 44)

	Sample Size	**Ratio**	**Savings**
Total Organic Repair NSNs	133538		$ 5,715,083.02
WR ALC NSNs	50732	0.380	$ 2,171,199.15
NSNs with Production Data	3189	0.063	$ 136,481.00
NSNs with Activity	593	0.186	$ 25,378.88
213 > 11 ships	213	0.359	$ 9,115.85
Random Sample	35	0.164	$ 1,497.91
***This assumes the ratios hold throughout**			

Conclusion

This thesis will continue the analysis of ways to select the retrograde transportation mode for reparable assets. This is accomplished by concentrating on the situation at the depot rather than just the priority of the asset (Kahler, 2004). This literature review provided a look at four areas applicable to this study. The review of reverse logistics, reparable item management and transportation mode selection provided the disciplines of logistics, and the previous studies gave the background and base for this research.

The literature showed reverse logistics has actually been in practice for some time, but only recently has become more important to industry as environmental laws tighten and resources become scarcer. It also showed that firms are starting to realize that by paying more attention to this segment of their pipelines they can actually improve costs savings and the efficiency of their operations. This trend toward more active management of reverse logistics is the base for this study.

Looking at the applicable regulations and studies on reparable item management gave an overview of the types of items that will be analyzed in this study and how the Air Force system for them operates. Two important issues for this study were revealed. First is that the Air Force bases its inventory on a transportation based system (Kahler, 2004; Kossow, 2003). This reliance on transportation rather than inventory appears to force the system to concentrate on the items' movement through and not how the whole system functions and how it could be made more cost effective. Second, the Air Force's inventory policy also calls for on-demand repair of items. This practice may result in low

completed inventories at the depot and make the depot's serviceable inventory position as a determinant of modal choice unsuccessful.

The literature showed that for the most part, the most important aspect in choosing a mode of transportation was service, followed closely by costs. It also showed, however, that not all aspects of service were always more important than costs and the ability to look at the total logistics cost function was necessary to decide which determinant was the most important for each situation.

Finally, previous research on Air Force transportation mode selection showed that while many items in both the forward and reverse segments of the pipeline appropriately travel by premium transportation, there are cases where a slower and less costly means should be used. In all the studies, a combination of the two types appeared to be the most cost effective way to move assets. The studies also showed that policies on movement of items should be altered, and that the inbound side of the depot's inventory could prove useful in determining mode of transportation. This thesis will continue this research and test the usefulness of the depot's inventory.

III. Methodology

Problem Statement

The purpose of this research is to expand on previous research and conduct a more in-depth analysis of whether the inventories of the Air Logistics Centers can be used to determine transportation mode. The literature review showed that current policies do not specifically dictate a mode of transportation. It does, however, indicate a need to move things quickly as the Air Force policy for inventory management relies on speed through the pipeline rather than large inventories (USAF, Jun 1998). The only determinant found was in the transportation regulations that based the mode on the priority of the asset (USAF, Nov 2003). This gives no consideration as to whether the depot already has more than its capacity can handle and does not consider the fact that the depot may have serviceable assets available to send back to the base. If either of these is true, then the asset should not be shipped by fast transportation since the depot will either not be able to get to it anyway, or the depot already has assets to meet demand. This thesis will determine the effectiveness of using the depot's inventory as a determinant of transportation mode for retrograde assets.

Research Paradigm

This thesis builds on previous research for which there is no commonly used methodology. Since there was no specific methodology found, this thesis will use an expanded version of the methodology used by Kahler (2004), which was modeled after Masciulli's (2001) and Kossow's (2003) methods. As with Kahler's (2004) study, the idea will be to look at the supply chain as a whole system and find when the conditions at

the depot indicate that fast transportation will not speed up the system and a slower, lower cost mode would be appropriate. This will be accomplished by using the depot's inbound (to be repaired) inventory and its outbound (serviceable) inventory to set the priority of shipment for an asset. Cost savings can then be found by a comparison of mode used to what mode would be acceptable based on the depot inventory.

Required Data

There are four basic types of data needed for this research and were fairly readily available. Three of these are basically the same type as those used by Kahler, and one provides the needed information for the extended research. All of these come from Air Force databases in supply**,** maintenance, and transportation. The supply data consists of depot pipeline and demand data. The maintenance data consists of production rates. The final piece of data comes from transportation shipment records.

Supply Data

Both types of supply data were provided by Headquarters Air Force Materiel Command, Directorate of Item Management**.** The pipeline data comes from the DO35K wholesale and retail receiving and shipping database. This database gives the inventory position of the reparable assets as they flow into, around and out of the depot. Since the DO35K is a living database that is updated continuously, this data consists of 18 "snapshots" from a one day out of the month of the inventory at the time the data was collected. The 18 points were taken over a period of time with points from October through December of 2001, January through March and May through August of 2002, and January through May and October through December of 2004. There are four

sections from this data needed for this study. First are the two for the outbound side of the depot. These are the amount of stock in transit out of the shop and the serviceable items in the depot's supply. These are represented by stock in condition codes INT FROM and A respectively. These are the assets the depot has serviceable and ready to be shipped out. The next two represent the items which are already at the depot and waiting to go into repair. The first are carcasses (Code F) which are in the depot's supply and waiting, while the second are assets which are in transit from depot supply to the shop (INT TO) where it will be repaired. These are the amount of items the depot has to work with.

The next piece of supply data will be used to determine the depot demand for each item. This data is generated by the Readiness Based Leveling (RBL) Production System database. This System runs on a quarterly basis using six data inputs from various Air Force Supply systems (AFMC, Oct 2004). It then runs an RBL Modeling program which provides several different databases used for various things like adjusting stock levels (AFMC, Oct 2004). The data base used for this thesis is the Central Leveling Summary. Along with a large amount of other types of information, it contains the data necessary to calculate the depot demand for each item. It shows the base demand and percent base repair for each base that uses a particular NSN. The depot demand for each item is calculated by taking the demand rate at the base for an item and multiplying it by the percentage deemed NRTS, which is just one minus the percent repaired at the base. Once this is found for an item at each base that uses it, they are summed to give the demand at the depot for the item. The entire equation for finding the depot demand for an item is given in 3-1:

[3-1] $$DepotDemand = \sum_{i=1}^{n} basedemand_n \times (1 - \%baserepair_n)$$

Production Data

There is still no good source to find capacity data, although as Kahler (2004) mentioned it would seem necessary to have for production planning and budgeting. Since this data is unavailable, a source for the surrogate measure, namely monthly production rate, developed by Kahler (2004) was found. The idea is to use actual production rates to give an estimate of the shop's capacity. This data was provided by Headquarters Air Force Materiel Command, Depot Operations Division, Process Improvement and Performance Branch, and consists of monthly production data for every reparable asset in the Air Force Inventory for Fiscal year 2002, 2003 and 2004. While this does not give a true capacity measure, it does provide a reasonable way to estimate it by looking at what the shop actually produced. The data also covers the period of operations in Afghanistan and Operation IRAQI FREEDOM, so the shops were most likely to be operating at a high tempo to keep up with the increased demand.

This data came from an Access database. It provided production data for every repairable item in the Air Force, so the database was filtered down several times to get the data needed for this thesis. First it was filtered to contain only those NSNs that list OC- ALC or OO-ALC at the source of repair. AFMCI 32-108 defines a source of repair as the agency where the items are actually sent for repair as opposed to just managing it (AFMC, Aug 1999). This filter ensures only items actually being repaired at one of the two depots of interest are included. Next, it was filtered to only include repairable items

identified by a National Stock Number and not as an end item (for example, before filtering, there were production rates for depot level repair of an entire aircraft). Also, very few items had production in all 36 months worth of data, so it was filtered again to contain only those with a production count in at least 30 of the 36. These were then reduced into a daily mean and standard deviation using an average of 21 work days per month. The requirement for at least 30 observations maintained a sufficiently large sample to assume normality based on the central limit theorem. This process generated a database with production for 953 items.

Transportation Data

As with several of the previous theses, this piece of data was provided by Headquarters Air Force Materiel Command's Logistics Support Office. The data is pulled from the DO87 "tracker" database, and contains shipping information for an asset. This data includes item type, condition, origin, destination, cost, and mode, just to name a few. These were provided to match up with the same day as the snapshot point in the DO35K data. The main pieces needed for this study will be origin, destination, size/weight, mode of transportation, and cost.

Although the data contains cost data, there were numerous holes in this section as well as many others, and will be discussed later in Chapter 5. Since the data is not complete enough, the cost savings calculations will be based on FEDEX rate tables.

Methodology

The first step for this study will be to filter the available data. This study is limited to OC-ALC and OO-ALC NSNs. As discussed previously, the production data

will first be pared down to include only items repaired at the two depots of interest. It will then be filtered to include only items with at least 30 or more of the 36 months of production to maintain a sufficiently large sample.

The next part of the filtering is to make sure the items in all the databases match up. Not all 953 items in the production database have matching data points in the supply data bases, so they will need to be pared down to a matching sample. This will be done by linking the databases and running a query to select items shown in all three tables. This will match the production, supply and demand databases. The Transportation data can then be filtered down to match as well. This will give the final group of NSNs used in this study. The transportation data will also be filtered to include only those shipments from CONUS locations to the depots using commercial air transportation.

Once the databases are matched up, the methodology will be a two-step comparison process and then a determination of potential savings. Like Kahlers' (2004) study, it will gauge the efficacy of the mode selection made. The first step of the comparison will be to compare the calculated daily depot demand rate to the depot's serviceable inventory, namely those items in condition codes INT FROM and A**.** The quantity of these two will be added together and then compared to the daily demand rate times the number of days for a particular mode. If the depot's inventory is greater than the demand rate times the number of days for that mode type, then the item can be shipped by that mode. Although there are not 18 observations of every NSN, a comparison will be made for each that are available. Equation 3-2 shows the calculations for this comparison. [3-2]

[3-2] DEPOT STOCK = INT FROM + A
IF DEPOT STOCK $\geq$ demand X (# of days): use mode for this number of days
IF DEPOT STOCK < demand X (# of days): use a faster mode

For those items where the depot stock is less than demand for the number of days in question, the second step comparison will be performed. This will be the comparison method developed by Kahler (2004). This involves a comparison of the depot's inbound stock, namely those in condition codes F (CARC) and those in transit to the shop floor (INT TO) with the average production rates from the production data plus three standard deviations ($\mu + 3\sigma$) (Kahler, 2004). If the amount of stock at the depot is greater than the average production rate times the number of days in question + 3σ, then again the shipping method for that number of days is appropriate. The idea is based on the empirical rule, which states 99.7% of all measurements fall within 3 standard deviations of the mean. Using Kahler's (2004) test, this will mean that 99.85% of the time, the depot's production rate will be less than $\mu + 3\sigma$. This will actually cause any savings to be underestimated since most of the time the depot's average production would be closer to the mean than 3σ. Equation 3-3 shows the calculations involved in this phase.

[3-3] DEPOT STOCK = CARC + INT TO
IF DEPOT STOCK $\geq \mu$ x (# of days) + 3σ: use mode for this number of days
IF DEPOT STOCK $\leq \mu$ x (# of days) + 3σ: use a faster mode

The comparison process will be done using query to assign a suggested mode with a series of nested if-then statements each criterion until one of the two is reached starting with five days for ground, then 3-day, and 2-day. Any case where the comparison fails for both 2-day constraints indicates that overnight is the appropriate mode. A conceptual model of the if-then comparison is shown in the Appendix.

Although in many cases ground shipping can take less than five days, it will be assumed to be the maximum five for this study.

The last part of the analysis will be to use the method used by Masciulli (2001), Kossow (2003), and Kahler (2004) to calculate potential savings of using the least cost mode. This will be accomplished by linking the transportation data with the results from the two comparisons by date and item to find all the instances where something was shipped by air on a date it could have gone by a lower cost mode.

Once this group of shipments has been identified, the cost savings will be found by using FEDEX's standard overnight rate as the rate for the mode used, and calculating the savings for 2-day,3-day, or ground rates, whichever is found to be appropriate for that item on that day. For each, the difference between the cost of mode used and the alternate will give the cost savings for that shipment. These savings will be summed to find the total savings from the period covered. These cost savings can then be compared to previous results by using Kahler's (2004) method of extrapolating back to the entire population by dividing the savings by the ratio of the NSNs used back out to the population.

IV. Analysis

Data File Preparation

In order to have a useable data set for the modal choice determination based on depot inventory position and potential cost savings calculations, the data files received had to be edited. All the data files were filtered down and matched into a useable set prior to the analysis

Production Data Preparation

The production data was received in a Microsoft Access database. It included the production totals for every organically repaired exchangeable item managed by the Headquarters Air Force Materiel Command, Depot Operations Division, Process Improvement and Performance Branch, some 8,726 items. The first step in paring this data down was to filter out the records for items repaired at the two depots of interest, Oklahoma City ALC, and Ogden ALC. The query for this filtering produced 6249 items. The next step was to insure only items that had at least 30 of the 36 months of production totals were included. A query was built to select only those with 30 or more data points and yielded 953 items. Once the useable set was identified, queries were set up to produce the daily mean and standard deviation for each NSN.

Supply Data Preparation

Both sets of supply data were also received in Microsoft Access databases. The first step in preparing the supply data was to create a query using equation 3-1 to generate the depot demand for each item in the demand database. Once this was accomplished,

the next step was to match the two supply data bases with the production database so that only NSNs that appeared in all three databases were included in the mode selection comparison. A query was developed that linked all three databases together based on NSN and generated the final table for the comparison with applicable supply inventory positions, production mean and standard deviation, and demand rate. This reduced the total number of NSNs in the study to 769. Although not every NSN kept in the table had an inventory postion data point for all 18 positions, any that appeared in all three databases were kept for comparison. This gave the final table a total of 13,308 records that were used to make a modal choice comparison.

Transportation Data Preparation

The transportation data was received in Text files to cover the eight days from 2004 in the mode comparison. Due to the fact that the DO87 database receives input from several transportation systems, it contains 100 different fields for each transportation record. Each system populates different fields so there were considerable gaps for each record, and in many cases there were data missing in too many of the fields needed for this study. To filter the data down to a useable set, the text files were imported into Microsoft Access and a query was run to filter the data down to those records that matched by date and NSN with the supply data. The file was then imported into Microsoft Excel. The records were then filtered to get rid of those that fall outside the scope of the study and those that had data missing in too many of the needed fields.

The first step taken to filter the records was to eliminate those that were not moved by commercial air. This was done by filtering on the mode and the two carrier

columns to eliminate all military air carriers and ground carriers. Any records with any of these fields blank were also eliminated. Next was to filter out all records that had a destination other than the two depots in the study. This was accomplished by scanning the five destination fields. Any destinations other than the two depots and those with all blank fields were eliminated. Then the records were filtered to make sure only CONUS origins were included. Like the destination filter, the 5 origin fields were scanned for overseas locations or missing data. Finally, the records were filtered by weight to eliminate any with blank fields. This process found a large number of heavy (greater than 150 lbs) items that had been shipped by overnight air. Rather than eliminate them from consideration, they were segregated into a separate group and cost savings calculated based on FEDEX's contract overnight, 2-day, and 3-day "hundred-weight" rates, which are calculated by multiplying the weight of the item times the rate per pound for the weight range of the item (for example standard overnight for items 150-299 lbs is $1.10 per lb).

Transportation Mode Selection

After filtering the data into usable sets, the modal selection comparison was performed on the 13,308 records of supply inventory position. A query was developed to assign each of the 13,308 records a mode based on the inventory position of the depot at the time. For each potential mode choice, the depot's serviceable inventory of condition A items and INTRANS FROM was compared to the number of days of demand for the mode in question, for example demand times five for ground, times 3 for 3-day, etc. Those that failed this comparison were then subjected to the capacity comparison for the

same number of days. The depot's NRTS inventory of condition F items and INTRANS TO were compared to the number of days times mean production rate for the mode plus 3 standard deviations. The comparison process continued down until one of the two criteria was met for the record. The following table shows the results of these comparisons.

Table 2. Results of Mode Choice Comparisons

	OC-LC	OO-ALC	total	SHIP:
total comparisons	6723	6585	13308	
More than 5 days of serviceable	3558	3590	7148	**Ground**
More than 5 days of carcasses	2747	2747	5494	**Ground**
More than 3 days of serviceable	59	48	107	**3-day**
More than 3 days of carcasses	72	60	132	**3-day**
More than 2 days of serviceable	18	10	28	**2-day**
More than 2 days of carcasses	68	25	93	**2-day**
Less than 2 days of either	201	105	306	**Overnight**

The next table shows the total number of items indicating each mode type and the percentage of the original 13,308:

Table 3. Modal Results and Percentage of Original 13,308

Totals	OC-ALC	OO-ALC	total	% of original 13308
Ship Ground	6305	6337	12642	95.00%
Ship 3-day	131	108	239	1.80%
Ship 2-day	86	35	121	0.91%
Ship Overnight	201	105	306	2.30%
Total less than O/N			13002	97.70%

Potential Cost Savings Analysis

After the results of the modal choice comparison were obtained, another query was developed which linked the filtered transportation data by NSN and date to the table generated by the modal choice. This allowed an assignment of mode to each of the shipments that matched a by date and NSN to the supply data. The NSNs in the comparison table had 972 transportation records from the eight days from 2004 in the DO35K records. This consisted of 863 small package records and 108 freight records. Table 4 shows the numbers of each type of mode assignments for the records:

Table 4. Mode Suggestion by Package Type

Mode	Small package	Freight	total
Overnight	5	1	6
2-day	6	1	7
3-day	23	107	130
Ground	829	N/A	829
Total	863	109	972

.

Table 5. Cost Savings Based on Mode Suggestion

shipment type	number	overnight	suggested mode	savings
small package	863	$28,910.11	$13,316.42	$15,593.69
freight	109	$34,531.20	$26,198.88	$8,332.32
total	972	$63,441	$39,515	$23,926

Overnight transportation costs were calculated for all shipments, and then the cost for the suggested mode was calculated. The difference between overnight and the mode suggested shows the potential for cost savings. The potential for costs savings is shown in table 5.

To estimate what savings might constitute when projected over the entire organically repaired exchangeable NSNs, Kahler's (2004) method of extrapolation was used. The estimate is done by dividing the amount of cost savings by the ratio formed from the dividing the sample from the next level up. For example, to extrapolate the savings of the 769 NSNs in all three tables to the 953 from the filtered production data, dividing 769 by 953 gives the ratio .806925. Dividing the cost savings of $23,926 by this ratio gives an extrapolated savings of $194,426.06 for the 953 items. This process was continued up through levels to the original 8,726 exchangables and finally to the 133,538 total reparable NSNs reported by Kahler as a basis for comparison. In order to use this extrapolation, two assumptions are needed. First, we must assume that the sample of 769 NSNs is representative of the rest of the population. Also, we must assume that the ratio of cost savings holds throughout as we go up through the levels. Table 6 shows the results of this extrapolation.

Table 6. Extrapolation of Savings

	size	ratio	savings
Total NSNs considered by kahler(2004)	133,538	0.065345	$4,154,787.42
Total Organically repaired exchangables	8,726	0.716136	$271,493.32
total OO and OG NSNs	6,249	0.152504	$194,426.06
NSNs with 30+ production	953	0.806925	$29,650.83
Matched sample	769		$23,926
Assumes ratio holds throughout and sample is representative			

These are savings for only 8 days. Using Kahler's (2004) method to annualize the savings, namely dividing the total savings by the ratio of 8/250 work days, the savings

would be $129,837,106.77 for the total group Kahler extrapolated to. For the exchangeable NSNs considered in this research, the savings would be $8,484,166.26 annually. Granted, these are most likely inflated given the restrictive assumptions, but even if they are off by as much as 90 percent, there is potential for $1.2 million in savings.

V. Conclusions

Thesis Objective Restated

This research sought to demonstrate the potential for savings if policies toward modal selection were relaxed (Kossow, 2003), and that the inventory already at the depot should be used as a factor in determining the mode of transportation for a reparable assets returning to the depot. The literature review found that although mode selection is not dictated by transportation regulations, current Air Force policy requires all retrograde reparable parts be shipped based on priority of the part itself and also requires expedited movement to the depot to support smaller inventories. This gives no consideration to what the condition of the rest of the pipeline is and whether fast transportation will actually speed up the flow. The goal of this research was to demonstrate the potential benefit of using the depot's inventory as a factor in mode selection without degrading the overall service level of the pipeline.

This thesis compared the serviceable inventory of the depot to its demand level and also the depot's unserviceable inventory to its capacity to find how often either one of these two indicated that premium (overnight) transportation was unnecessary and a waste of resources. It also analyzed potential savings if these two conditions were used to suggest the mode selection for a retrograde reparable.

Review of the Investigative Questions

The literature review provided answers to the first two investigative questions. For the first, what factors determine modal selection in both the Air Force and civilian industry, the literature showed that for the most part, the most important aspect in

choosing a mode of transportation was service, followed closely by costs. It also showed, however, if service level is the same, the cost is generally the next most important factor. Many of the authors noted the need to be able to look at the total logistics cost function to pick which determinant was the most important for each situation.

The second question asked when a slower mode of transportation is appropriate for Air Force reparable assets and when is it not. The review of previous research on Air Force transportation mode selection showed that maintaining the required service level dictated when a slower mode would suffice. The research also showed that there are cases where a slower and less costly means should be used and that a combination of both fast and slow transportation appeared to be the most cost effective way to move assets and still maintain the needed service level.

Questions three and four were answered by the comparison of the two types of inventory at the depot. For question three, the results showed that out of 13,308 inventory comparisons, 7,283 or 54.73% of the inventories had at least enough serviceable items to use 2-day shipping or slower, with 7,148 of those indicating five days or more of inventory and ground transportation being appropriate. For the remaining 6,025 inventory comparisons, 5,719 or almost 43% of all comparison indicated more carcasses than the depot could repair in two or more days. Of these, 5,494 indicated that a ground mode would be appropriate. Overall, the two comparisons found that over 97% of the time, the depot’s inventory position is such that using overnight transportation is unnecessary, and in fact, that 95% of the time ground transportation would suffice.

The final question asked what cost savings would be if depot stock level indicates a slower mode would be acceptable. Using the mode suggested by the inventory comparisons found that for the 972 transportation records considered, a total savings of $23,926 would be available if the least cost FEDEX mode were used over standard overnight. Extrapolating these to an annual rate for the types of items considered in this research, namely organically repaired exchangeable items, would provide a potential for almost $8.5 million, assuming that the sample used was representative and that the ratios held moving up levels.

Conclusions

Stock and Lambert (2001) point out that the objective of a logistics system should be to minimize the total logistics cost of the system once the required service level has been met. Although there are times when using the fastest mode of transportation is the best way to meet Air Force requirements, this research has found that there are a large number of occasions where using fast transportation does not improve the service level. The primary research question of this thesis was: can the serviceable inventory position in relation to demand from bases and the NRTS inventory position in relation to repair capacity of the depots to be used to determine the best transportation mode for repairable items? The results of the analysis show that these inventories can be used to pick the best mode of transportation. This research confirms previous results that indicated the depot's capacity could be used as a factor and shows the serviceable inventory could prove useful as well.

In his book *The Goal*, Eli Goldratt (1992) suggests that the goal of a manufacturing process should be to maximize throughput and minimize costs. For the Air Force pipeline, this would mean getting an unserviceable part to the depot, repaired and back to the base. He also points out that any system, such as the reparable pipeline will have a bottleneck, or slowest point, and any processes in the chain prior to the bottleneck should not operate any faster than the speed of the bottleneck process, as this will just waste resources and not speed up the system (Goldratt, 1992). If the depot is considered the bottleneck based on its carcass inventory, shipping reparable items back by fast transportation will only add to the backlog of waiting carcasses and money wasted since the fast transportation did nothing to speed the process. The large number of instances where the depot's inventory suggested a slower mode would be acceptable indicates the Air Force needs to consider the entire pipeline as a system and not try to optimize each segment individually. Each section should be optimized, but only to the extent it shortens the entire cycle. Anything beyond this point is a waste of resources as does nothing to speed up the process of a part going from base, into depot repair, and back. By doing so, the Air Force could significantly reduce its transportation costs without changing the service level of getting parts back to the bases.

There are two other points about this research that make the need to consider changing the Air Force mode selection important. First, the potential cost savings found in this research are very conservative. All ground mode comparisons were based on the maximum five day delivery time. While this is true for some shipments, many bases in the CONUS are much closer to one or more of the depots and the travel time even by ground can be as little as one day. Like Masciulli's 2001 research, there were several

shipments sent by express air from the Oklahoma Air National Guard in Tulsa to the Air Logistic Center in Oklahoma City, a distance of just over 100 miles. This is a situation where air transportation should never be used in any circumstance. In addition, the cost savings calculations used the FEDEX standard commercial ground rate. If ground shipment became more of the norm, these rates could be set by a competitive contract like the air rates, which are much lower than the commercial rates. There is also no consideration in these savings of using some consolidation. Kossow (2002) has already shown an improvement in costs by using at least some consolidation of shipments. If bases held onto items long enough to get a full truckload rate, these savings would be even larger. Secondly, the saving potential found in this research is real cost saving that could be achieved immediately. We would simply be spending less money and still get reparable items through the pipeline in the same amount of time.

Recommended Research

While this study expanded on potential ways to improve Air Force transportation mode selection, there is still a large number of areas left to examine. First, the idea of consolidation has shown great potential for cost savings, but research is needed to see if bases have the capacity to store items long enough to generate consolidated loads. This would require examining each traffic management office's surface freight area to measure its capacity to store and consolidate shipments. Both this study and Kahler's (2004) concentrated on items repaired organically at an Air Logistics Center and moved within the CONUS. There are a large number of items shipped directly to depot from overseas locations or repaired through contract. Research in these areas would confirm

or deny that fast transportation is not always necessary to meet service requirements across all reparable items.

Another area of study previously mentioned by Kahler is how to determine the depot situation and communicate it to the freight handler to base their mode selection on. First, research is needed to find a more accurate way to determine the repair capacity of the depot. Then research would be needed to find the best system to allow the freight handler the visibility needed to make the mode decision.

Finally, there are several areas not directly related to this problem that presented opportunity for research during the analysis. First, it was interesting to find that the three different databases used in the mode comparison did not have all the same stock numbers included, even though the 963 selected out of the production data were actively produced over three years. A study to find out why a discrepancy exists between the databases could prove very useful to the owners of those datbases. A similar study could be performed on how data is populated into the DO87 "tracker" database that provided the transportation records. There are several different systems feeding data to it and each populates a certain group of the redundant fields. Even so, there was quite often data missing which caused a large number of records to be eliminated from consideration. Research could look into why the different systems cannot populate one set of fields and what causes the loss of data that should be transferred into the database.

Appendix

Nested if-then comparison for mode selection:

DDR = Daily demand rate
DC = daily mean repair capacity
FI = serviceable inventory
WI = unserviceable inventory

START

1. FI >= DDR(5)? Yes -- **GROUND**
No
2. WI >= DC(5)+3σ? Yes -- **GROUND**
No
3. FI >= DDR(3)? Yes -- **3-day**
No
4. WI >= DC(3)+3σ? Yes -- **3-day**
No
5. FI >= DDR(2)? Yes -- **2-day**
No
6. WI.>= DC(2)+3σ? Yes -- **2-day**
No
Go **overnight**

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14. ABSTRACT

Air Force logistics policies direct the "expedited evacuation of reparables … to the source of repair", in an effort to allow smaller inventories. Transportation Mode selection is based only on the asset itself. This focus works well when shipping assets out from the depot to a base. When a base ships an asset back to the depot however, the priority of the asset may not be the best way to select the transportation mode. The quantity of the assets at the depot may indicate that fast transportation is unnecessary. The depot may already have enough serviceable assets to meet demand or the number of unserviceable assets already waiting exceeds the depot's repair capacity. If either of these inventory conditions exists, shipping an asset back to the depot using fast transportation is unnecessary and shipping the item via a slower and less costly mode could maintain the same service level. Rather than focus solely on the asset, the inventory of the depot should be involved in mode determination.

This research evaluated current Air Force retrograde transportation mode selection policy. Demand and production data were compared to supply data for Oklahoma City ALC and Ogden ALC to use the inventory position of the depot to select the appropriate speed of transportation. Transportation data was then used to find cost saving potential by finding the difference between mode used and the mode indicated by the depot's inventory position. The analysis found that in 97% of the trials, a mode slower than overnight was suggested and produced a potential cost savings of 38%.

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